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Minimum information required for written word recognition

Deok-Hee Kim-Dufor (dh.kimdufor@telecom-bretagne.eu)*

Philippe Tigréat (philippe.tigreat@telecom-bretagne.eu)

Claude Berrou (claud.berrou@telecom-bretagne.eu)

Département Electronique, Télécom Bretagne, Institut Mines-Télécom, France

Lab-STICC, CNRS, UMR 6285

Abstract

Reading is an automated process. One of the remarkable human abilities is that we can read even partially erased or hidden words. We carried out a study on written word recognition in order to decipher how much information is required at least to identify a word. Experimental software was designed in C++ language to measure the amount of information in pixels and reaction time. The results showed we could identify words at a very low display rate and suggest that prior knowledge on the category of words play a mediating role in written word recognition.

1. Introduction

As soon as we see something written such as a signboard, we automatically read it. Reading is, indeed, an automated process wherein two types of processing – that is, bottom-up and top-down processing – interact (Treiman, 2001). This automation of reading has been considerably proven namely by the Stroop effect (Stroop, 1935) that has been replicated over 700 times (MacLeod, 1991). When we read a word we have never seen, the main thing of reading process occurs in a bottom-up way; top down processing plays a key role in reading words we know and partially erased or hidden words as well. In the latter case, how much information at least do we need to recognize a word? Some studies on written word recognition have been carried out from different angles such as contrast energy (Pelli *et al.*, 2003) and letter fragmentation (Jiang and Wang, 2006; Jiang *et al.*, 2010). Is recognition of a partially presented word easier when we know its category? To answer these questions, we designed experimental software in C++ to measure the amount of information in pixels necessary for written word recognition and verify a possible category effect.

* Corresponding author

2. Experiment

2.1. Paradigm and Stimuli

Our experiment consisted in recognizing pixelated words that were partially presented. It had three sessions, and each of them corresponded to a category – living things (plants and animals), animals and mammals – with twenty 4- to 9-letter French words. The lexical stimuli were selected from the French lexical database Lexique 3.80. Each session had a group of ten high frequency words and that of ten low frequency words. Across sessions, word frequency was maintained equal on average for both lists (see Table 1). The number of words with different lengths – short for 4- to 5- letter words; medium for 6- to 7-letter words; and long for 8- to 9- letter words – was balanced as well. Ten words were supplementarily chosen for a training test. Each word was pixelated; only the pixels composing letters, *i.e.* black pixels, were counted in summation of the amount of display rate. The pixels of each word displayed and the order of words were random in each round. The initial display rate was 0.25%, then 0.5%, and increased following an increment of 0.5% as shown in Figure 1. The order of sessions was balanced. This experimental software was built using the C++ programming language along with the Qt library.

	Living things	Animals	Mammals
Whole	17.261	17.035	17.0415
High frequency	34.168	33.717	33.731
Low frequency	0.354	0.353	0.352

Table 1. Mean word frequencies of each session

2.2. Participants

Twenty-three volunteers working at Télécom Bretagne signed an informed consent form and participated in this experiment. They were 14 males and 9 females whose mean age was 39 years 5 months. All were native French speakers with normal or corrected-to-normal vision. Eleven persons were not informed of the categories (1st group) and the other twelve persons were in the informed (2nd) group.

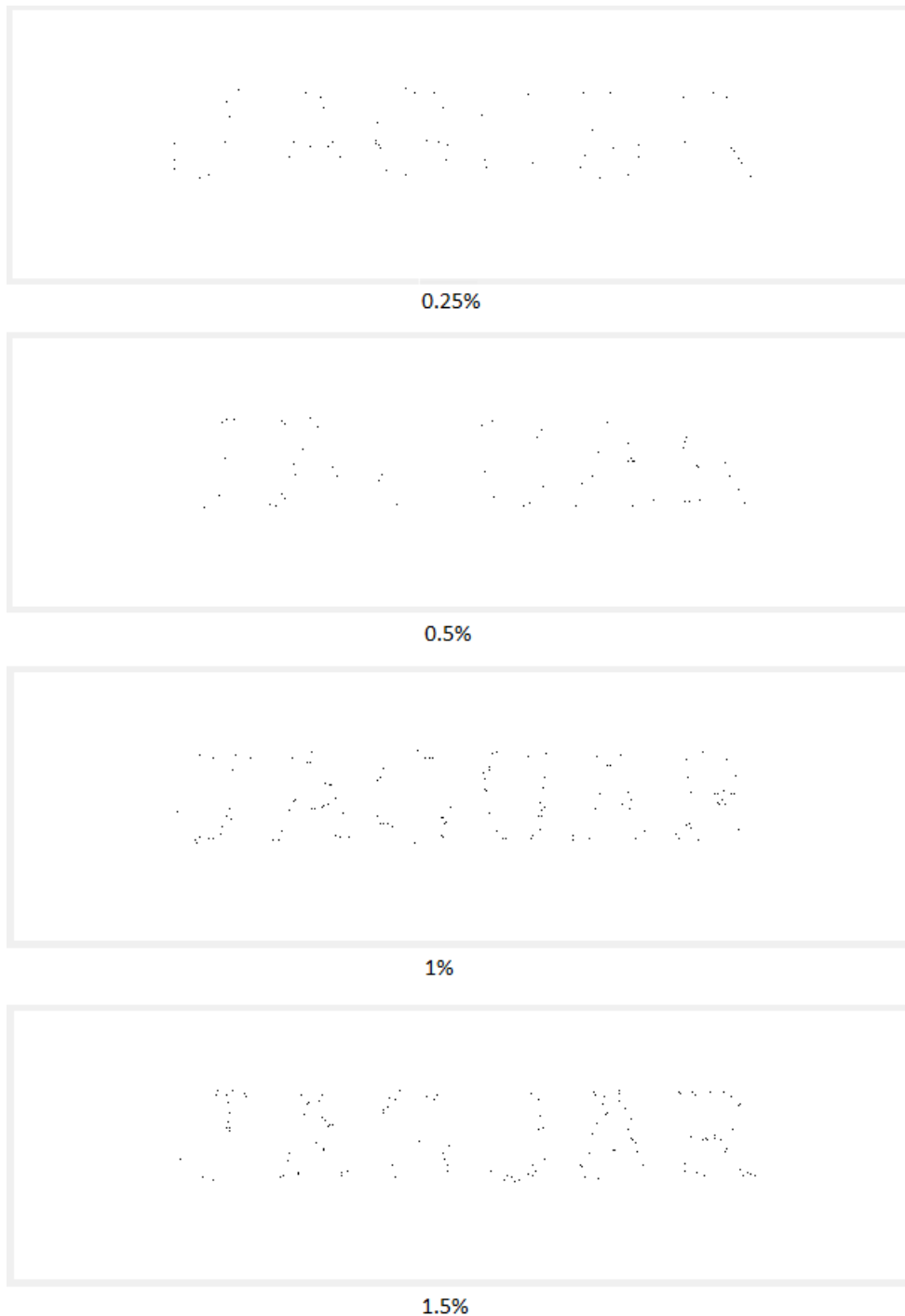


Figure 1. A pixelated sample word 'JAGUAR'

2.3. Materials and Procedure

A DELL latitude E6530 laptop computer and a DELL KB212-B keyboard were used to run the experiment and a DELL S2240L LED Full HD screen for display. The LED resolution was 1920 x 1080 at 60 Hertz, and the screen size was 61cm. The font was Courier, all letters were in uppercase, and each letter of words was displayed in a 77×70 pixel frame. Allowing for the angle of view for reading (5° to 10° for each eye), the longest words were no more than 21.83cm long.

The experiment took place in a quiet room wherein the screen and the keyboard were placed in front of the participant. The distance between the screen and the participant was 103cm. When the experiment started, the instructions were displayed on the screen, accompanied by the experimenter's verbal explanation. When the participants felt ready, they pressed the enter key to start each session. A fixation cross appeared for 500ms, followed by a pixelated (target) word for 350ms, then a white screen for 2000ms (see figure 2). The participants were asked to read each word displayed on the screen. In the case that they did not identify the word displayed, they let the sequence pass. As soon as they recognized the word, they pressed the space bar to stop the sequence, and then typed the word they had just recognized. Typing was not time-limited; only reaction time (RT) was measured. When they finished typing the word, they pressed again the space bar to resume the sequence. When the participants thought that they made a mistake while typing, they pressed the backspace key to erase the letters they had just typed in order to restart typing.



Figure 2. Configuration of each word presentation in the experiment

3. Results

The incorrect answers due to motor or orthographic errors were reclassified as correct answers. Motor errors are when the participant typed one of the letter keys right around the correct letter key. The words unknown to each participant were excluded from the data. We carried out multi-factorial ANOVA analyses considering only the correct answers.

As shown in Table 2, the incorrectly identified words were recognized at a significantly lower display rate than the correctly identified words ($P < 0.0001$) in both groups. Reaction time was shorter when words were correctly identified ($P = 0.0008$).

	%	RT
Correct answers	2.7826	864.2748
Incorrect answers	1.9084	929.3790
P	<0.0001	0.0008

Table 2. Display rate (%) and reaction time (RT) in both groups

The group that was not informed of the categories (1st group) was significantly slower ($P=0.0091$) than the informed group (2nd group), see Figure 3. No significant difference was observed between the two groups in terms of display rate, see Table 3. In order to determine the minimum amount of information for written word recognition, correct and incorrect answers of all participants were compared at each display rate (%). Significant difference between these two types of answers indicates the minimum amount of information necessary for written word recognition, *i.e.* when the number of correct answers becomes significantly greater than the amount of incorrect responses. Most participants started correctly identifying words at 1% (see Figure 4).

	%	RT
1 st group (not informed)	2.8202	876.2864
2 nd group (informed)	2.7360	852.8486
P	0.2525	0.0091

	F	P
Group	6.81	0.0091
Category	3.33	0.0362

Table 3. Group comparison and multi-factorial ANOVA for reaction time

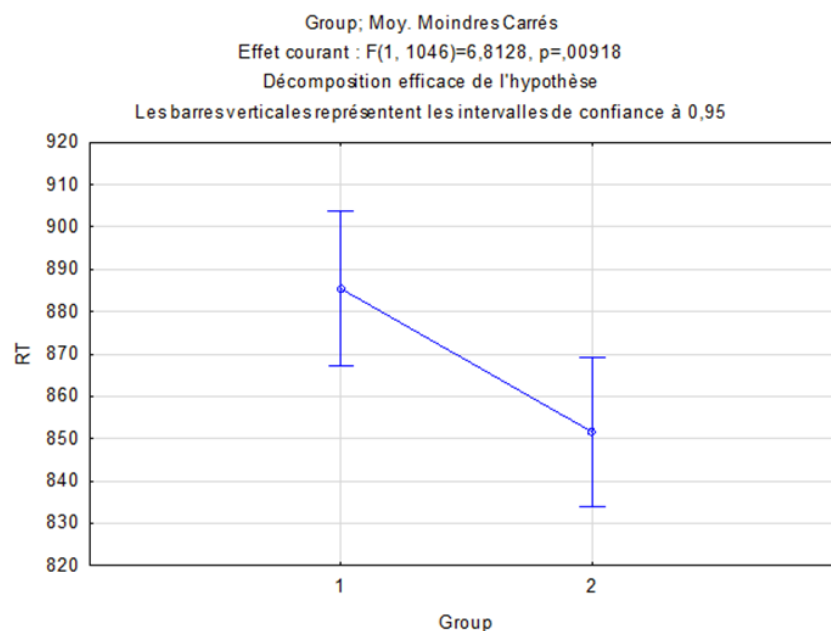


Figure 3. Group effect in reaction time (RT)

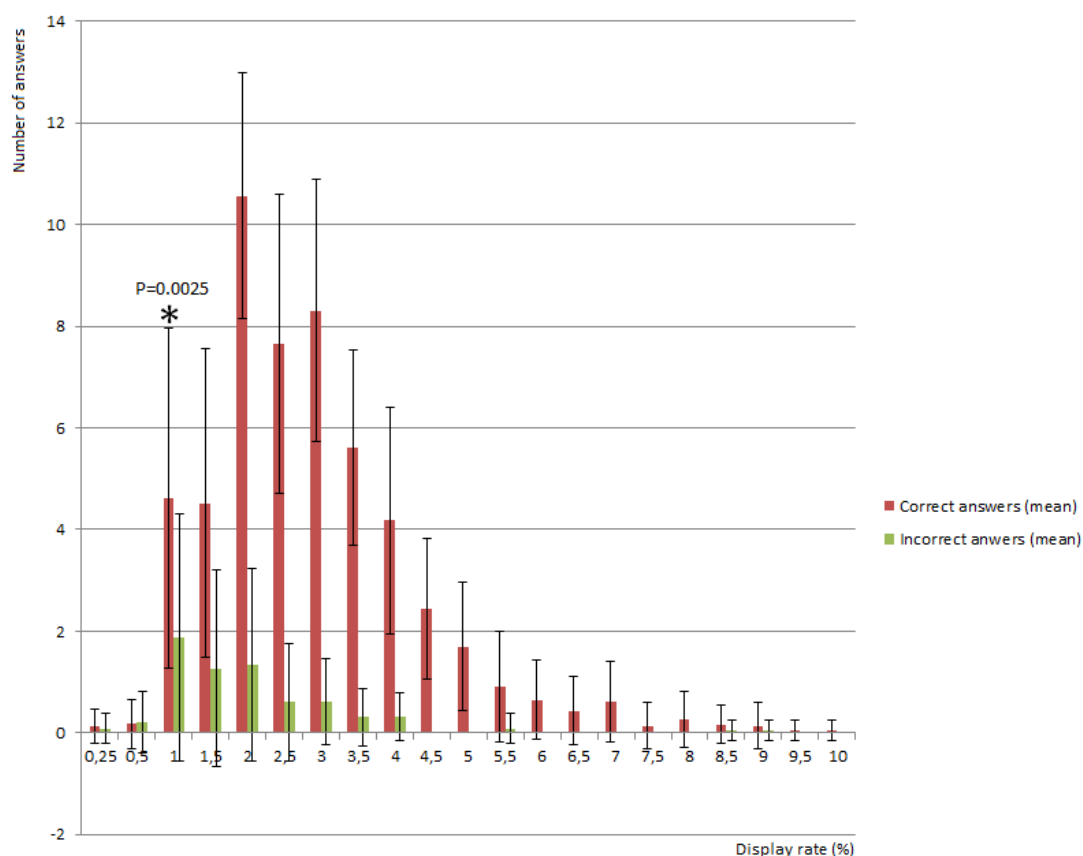


Figure 4. The minimum amount of information necessary for written word recognition in all participants

4. Discussion

The aim of our study was to measure the minimum amount of information necessary for written word recognition and to verify a possible category effect. Comparison between correct answers and incorrect answers showed significant differences in favor of correct answers in terms of reaction time, and of incorrect answers with regard to display rate. This negative interaction could be explained as follows: at lower display rates the participant has less information, this lack of information would increase the time necessary for the participant to respond.

In group comparison, no significant difference was observed in display rate. As to reaction time, the second group that was informed of categories responded significantly more quickly. It could be argued that knowing the context – the category in our study – plays a moderating role and hence facilitates word recognition by accelerating reaction time without changing the minimum amount of information (display rate) necessary for word recognition. This facilitation is due to the well-known top-down effect (Wheatley et al. 2005; Neely, 1991) in the scientific literature of psycholinguistics. The orthographic errors that the participants made in our study prove the top-down effect in

recognition processes of partially presented pixelated words. When they got a clue of the target word, they used their orthographic knowledge rather than a “copy and paste” process. This top-down effect proves the existence of category/context effect in our experiment.

The human ability to read correctly partially erased words is processed by dint of a combination between top-down and bottom-up processing in reading (Treiman, 2001). We thus tried to measure the minimum amount of information needed to recognize partially presented pixelated words. The result showed that the display rate at which the participants started giving significantly more correct answers than incorrect answers was 1%. This amount of information only takes account of black pixels. Do white pixels constituting blanks in letters really provide no information? If they contain some information, is it equivalent to that of black pixels? What role do pixel positions play in recognition? In the face of these thorny questions, we chose to consider only black pixels in the present study. The minimum amount that we found may therefore not be very precise, but it may be quite close to what we have been seeking.

5. Conclusion and further research

The minimum amount of information necessary for written word recognition was measured by means of the proportions of black pixels displayed. It was shown that the minimum amount was 1% of all black pixels of a word. Knowing the category of words in advance of each session helped the participants respond significantly more quickly. However, having this top-down influence did not diminish the display rate necessary to recognize words. This temporal enhancement is due to more information available, *i.e.* better top-down processing (words *vs.* a particular category of words). The category/context effect in our study is therefore directly linked to top-down effect.

As mentioned in the discussion part, it will be necessary to compensate the defect by means of further studies. It is fundamental to determine the value of white pixels and the importance of pixel positions. Since some same words were identified at very different display rates, only the positions of pixels would be the main determinant. It is thus required to discern pixels that are more important for recognition, if any. With this aim in view, an analysis is ongoing to calculate information density of each pixel. If this information density turns out to be important for word recognition, it will give rise to a new experiment using only pixels crucial to recognition at a very low display rate and/or using pixels shared by most letters at a very high display rate. In company with information density, pixel locations and distances will be taken into account as well.

The results will confirm or invalidate our hypothesis that the position of pixels is central to written word recognition.

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